MANAGING THE CFC-FREE TRANSITION ...THE CHALLENGE OF OZONE DEPLETION AND GLOBAL CLIMATE CHANGE

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ABSTRACT

In the 1980's efficiency challenges presented to the HVAC industry and building managers in the 1970's, became even greater. A United Nations agreement called the Montreal Protocol, signed in 1987, mandated that CFC's would have to be phased out of production by January 1, 1996, because of indications that CFC's were damaging the stratospheric ozone layer. Thus the industry was forced to find alternative refrigerant chemicals, while developing new equipment that could use the alternatives in an efficient way.

Now, on an apparent schedule 10 years later than that of the Montreal Protocol, the international treaty recently negotiated and drafted in Kyoto, Japan puts in place a similar protocol to control emissions of greenhouse gases. While the ultimate affect of this proposed treaty is still being evaluated, it is clear that attaining the highest efficiency economically possible will be the key in the future in order to meeting the goals set forth by this treaty. The HVAC industry will play a key role in this by bringing products and system designs to attain this performance in buildings.

After development of two major alternative refrigerants to comply with the Montreal Protocol, HCFC-123 and HFC-134a, the HVAC industry had to redesign large air conditioning chillers in order to efficiently use the alternative refrigerants. Today, new chiller designs, working in concert with efficient building

cooling systems, result in energy efficiencies far greater than could be attained only a few years ago.

The new reality of the CFC production phaseout and better-than-ever chiller efficiency offer new opportunities to building managers to save money while protecting the environment by containing existing CFC stocks, converting selected existing chillers and replacing others with more efficient machinery.

OVERVIEW

The development of stable, safe and commercially available CFC refrigerants in the 1930s ushered in tremendous changes in the way we lived and in the way buildings were designed. Air conditioning affected every aspect of our lives: Homes, cars, restaurants, and the office buildings where we work. Prior to air conditioning, office buildings *were* designed so that all occupied spaces had access to windows because the windows were the air conditioning. As a result, office buildings were tall and skinny. Air conditioning allowed buildings to be designed in any conceivable shape since proximity to a window was no longer important.

THE CHALLENGE OF CHANGE

Things have changed a lot since the 1930's. In the 1970's, increasing energy costs and energy crises led architects and engineers to design buildings with greater energy efficiency. More energy efficient buildings relied primarily on a "tight" design. Windows no longer opened and occupant comfort came to rely on heating, ventilating and air conditioning systems. Chillers provided the cooling capacity, using...more often than not...CFC-based refrigerants. Pressures to continually improve energy efficiency have resulted in chillers today that are significantly less costly to operate than they were only a few years ago.

The efficiency challenges to the heating, ventilating and air conditioning (HVAC) industry, particularly to air conditioning, grew even more complex in the 1980's. CFC refrigerants have dramatically changed our lives and now CFC refrigerants are no longer in production. The agreement, known as the Montreal Protocol, phased out production of CFC's on January 1, 1996, in order to protect the ozone layer.[1] The future availability of adequate quantities of CFC's to service existing installed HVAC equipment and guarantee the working environments and productivity of our building necessitates a planning process to become CFC-Free. The change that CFC's made on our lives was dramatic. The change we now face in replacing CFC's is equally dramatic.

In the 1990's and into the next century, the broader goals of controlling global climate change will present an even greater challenge to the building and design community.

The decisions of building owners, managers, or designers is critical to the success of your building, its productivity, its business, and it has important implications for the environment. Owners and users of CFC-based equipment who have relied on these refrigerants for many years will now have to find alternatives. Building owners and managers will need to operate equipment differently; will, at some point, have to retrofit or replace equipment; will have to keep more precise records and will have to train employees differently. In short, make a lot of changes. The HVAC industry is also faced with change, the biggest change it has faced since its birth. Complete redesign of an entire product line to ensure compatibility and efficiency with the new refrigerants.

Needless to say, these changes present unique challenges to both the users of refrigerants and the manufacturers of air conditioning equipment. But the bottom line remains the same: Buildings must remain comfortable and tenants productive.

The HVAC industry is faced with the twin challenge of phasing out CFC's and with providing our customers with energy efficient equipment. We need to supply solutions to our customers' CFC transition needs and do it with safe, reliable and efficient equipment. This is a huge challenge for us.

THE CHALLENGE TO BUILDING OWNERS AND MANAGERS

Let's look at the challenge of an existing building using CFC refrigerants. How do we evaluate the options? Does the manufacturer of an existing chillers offer a retrofit option? What will the chiller efficiency be after retrofit when compared to the original or compared to a new chiller? What will the economic impact be of retrofit versus replace? If the analysis has not begun it should be started soon, since these are complex issues.

There are four steps we will all take together to meet the challenges we share. After overcoming denial, three options exist: containment, conversion or replacement. For the reasons cited above, everyone needs to get out of the denial phase as quickly as possible. The clock is running, the challenges are great and there are opportunities to be gained from prompt and thorough attention.

So, without dwelling on the dangers of lingering in the denial phase, let's briefly discuss containment, which is driven right now by two factors: government regulations and economics ... the desire to conserve remaining stocks of CFC’s. Containment simply means that there are certain things that owners will have to do (or have had to do for some time now):

- Since July 1, 1992, technicians are no longer allowed to voluntarily vent CFC and HCFC refrigerants.
- Since 1994, the voluntary venting of HFC refrigerants is also no longer allowed.
- Under the Clean Air Act, service technicians must receive the appropriate training and will need to be certified.
- Purchase and use records for refrigerants must be kept.
- For both economic and environmental reasons, containment is right for every refrigerant: CFC’s, HCFC’s and HFC’s.

In terms of the things that can voluntarily be done to conserve existing stockpiles of CFC’s, an excellent example is replacement of older purge systems on low-pressure chillers with new high-efficiency purge systems. Because of the things that have to be done and the additional things that can be done to contain CFC’s, building owners and managers should be constructively engaged in this phase.

THE CONVERSION/REPLACEMENT PROCESS

After devising a plan to contain all refrigerants, the next question is whether to replace existing HVAC systems or to convert systems to operate on environmentally-acceptable CFC replacements. This decision is typically the most difficult, involving the most significant investments. Like any significant investment, careful evaluation and analysis of the options is required. The standard decision-making process involves five basic steps:

1. Recognize and define the problem.
2. Gather facts and make assumptions needed to define the scope of the solution.

3. Develop possible solutions to the problem.
4. Analyze and compare possible solutions.
5. Select the best solution to the problem.

Based on the fact that CFC’s are being phased out...and phased out rapidly with production having ceased on January 1, 1996...there is little difficulty in recognizing and defining the problem. Actually, rather than a problem, the requirement to convert to non-CFC machinery is more of an opportunity; an opportunity that offers cost savings through improved energy efficiency. But let's not get ahead of ourselves.

Gathering facts and making assumptions necessary to begin defining solutions should begin with a building load analysis.

The building load analysis is important because things may have changed since the original design: Reduced load due to lighting retrofits, change in use or occupancy, added load due to computers, people, etc.

Defining the problem continues with categorizing the machines relative to their age, efficiencies, service and maintenance expense, leakage of refrigerant and so on. A good way of beginning an analysis is to bracket the chillers into three age categories: 2-10 years, 10-20 years and over 20 years.

CHILLERS 20 YEARS OLD AND BEYOND

Chillers in this category are frequently good candidates for replacement because they are beginning to reach the end of their useful life. In addition, new chillers are much more efficient than the chillers of 20 to 30 years ago, as we discussed earlier. To cite a typical example, an early 1970’s water-cooled centrifugal chiller would have efficiencies in the range of 0.8 - 1.0 kW/ton. Today's water-cooled centrifugal chillers reach efficiencies in the range of .49 -.65 kW/ton or better.

Even in a typical office building, where operating hours are much less than a hospital or process cooling application, this difference in efficiency can frequently result in a three-year payback or less. This is extremely advantageous, because even with a three-year payback, the entire changeout and chiller installation can be financed. And the monthly interest and principal payments will be less than the monthly energy savings (a payback is the amount of time necessary for a an investment to pay for itself. In this case, the payback results from energy cost savings). Therefore, from day one, the owner will experience a positive cashflow. This is obviously very attractive to any facility manager.

While ozone depletion potential was the cause for the worldwide phaseout of CFC’s, there are a number of other environmental factors of refrigerant chemicals and the equipment that use them that should be considered when new systems are evaluated. These include energy efficiency and global warming potential.

Energy Efficiency

As for refrigerants, there are three common non-CFC alternatives: HCFC-123. HFC-134a. HCFC-22.

First, concerning the CFC alternative HCFC-123. HCFC-123 has the highest thermodynamic cycle efficiency of all the alternatives.[2] Again, efficiencies obtained over the 20-30 year lifetime of a chiller can translate into significant cost savings.

In the following example, a quick comparison of two chillers illustrates the importance of apparently small efficiency differences. **In fact, an efficiency difference of .10 kW/ton in a typical 500-ton application can mean an operating cost savings of $300,000 over the lifetime of the equipment; an amount that is more than double the entire cost of the machine..**

- 0.50 kW/ton HCFC-123 centrifugal chiller compared to a 0.60 kW/ton HFC-134a centrifugal chiller. Assume $.10/kwh energy cost, including demand.
- 500 tons x 2000 equivalent full load hours (EFLH) x .10 kW/ton efficiency difference[3] x $.10/kwh = $10,000/year savings.
- $10,000/year x 30 years = $300,000 energy cost savings over 30-year lifetime of the more efficient chiller.

Clearly, this is a simplistic evaluation. It illustrates, however, the importance that Life Cycle Costing evaluation plays in the ultimate decision of what is truly cost effective. Inefficient, lower first cost chiller equipment may not be in the long term best interest of the use and should be evaluated. In the Federal Government, the GSA Basic Ordering Agreement for Centrifugal and Helical Rotary Chillers uses a Life Cycle Cost evaluation technique as the basis for award. The energy and environmental savings demonstrated by this purchasing process are quite remarkable and should not be ignored.

Global Warming

On December 8, 1997, the Kyoto International Climate Change Summit yielded an agreement to embark on a protocol (treaty) similar to the Montreal Protocol, which would reduce greenhouse gas emissions, most notable for the HVAC industry, CO_2 , and HFC’s. Since mankind’s CO_2 contribution to the environment is principally caused by the burning of fossil fuels for production of electricity, the ultimate conservation of electrical energy in the future will be the principal path to compliance with the mandates set forth by the new treaty.

Furthermore, refrigerants themselves contribute to global warming, either directly by virtue of their release to the environment, or indirectly by virtue of their use in products that consume electricity – Direct Effect, and Indirect effect Global Warming Potential, respectively.

HCFC-123 has the lowest direct effect GWP (Global Warming Potential) for all of the alternative refrigerants. Furthermore, since HCFC-123 chillers are typically from 5 to 15 percent more efficient than chillers using HFC-134a or HCFC-22, the refrigerant also has a very low indirect effect GWP compared to alternatives. Current state of the art in HCFC-123 chiller design provides performance at .48 kW/ton or better at ARI conditions in many sized today and will be selectable across the entire product line from 300 to nearly 1200 ton capacity by the end of 1998.

HFC-134a and HCFC-22 centrifugal chillers, operating at higher pressures with inherently less efficient refrigerants, are typically limited to a 0.56 kW/ton level or higher. Although some machines using HFC-134a and HCFC-22 reach efficiencies down to 0.54 kW/ton (at ARI conditions), these efficiencies are available in a limited number of "sweet" spots throughout the product line.

Ozone Depletion

HCFC-123 has an extremely low ozone depletion potential (ODP=0.017) Additionally, HCFC-123 is a low-pressure refrigerant which makes it inherently less likely to leak, since internal pressures are frequently below atmospheric pressures. An accidental puncture to a machine would tend to leak air **in** rather than leak refrigerant **out**.

HCFC-123 chillers, because of their low-pressure design and incremental improvements that have been made over the years, are achieving "near zero" refrigerant emissions levels. Current emissions rate of less than 0.5 percent of the refrigerant charge per year represents more than a 50-fold reduction in chiller refrigerant emissions over designs just seven years ago.

During normal operation, the latest chillers include electronic early warning systems to detect and alarm chiller leaks. These controls alarm at the first indication of unusual purge operation. They directly monitor the presence of refrigerant that has escaped from the chiller. The loss of refrigerant due to unnoticed catastrophic leaks is thereby virtually eliminated. Professionals in the HVAC industry should become familiar with the guidelines set forth in ASHRAE Guideline 3-1990, *Reducing Emissions of Fully Halogenated Chlorofluorocarbon (CFC) Refrigerants in Refrigeration and Air Equipment and Applications*.[4]

Just as an example, the ASHRAE guideline contains two important elements, and I quote:

- "*Significant loss of refrigerant can be attributed to improper operation and monitoring of equipment operation. Routine operating logs should be kept so that the operator knows how much refrigerant and oil are used.*
- *A periodic review of logged condenser performance data can show the presence of air in-leakage or fouled heat exchanger surfaces...*"[5]

Today, keeping accurate, timely operating logs has never been simpler. Microprocessor-based control systems make recording of critical operating information simple and routine, and require minimal manual input from an operator. Even more importantly, these systems automatically calculate and display the data the operator needs to make informed decisions. For example, these controls produce reports that list not only the condenser approach temperature, but also list it over a period of time so the operator or service engineer can identify trends. To take it one step further, an operator or service company can be automatically notified if operating conditions exceed set parameters.

Historically, leaks have accounted for over 41 percent of the refrigerant loss. Flare fittings have been identified as a major contributor to these leaks. To meet this challenge, "near zero" centrifugal chillers have over 85 percent fewer flare fittings than machines produced just seven years ago.

Purge emissions of refrigerants have been reduced in some cases to less than 0.0049 pounds of refrigerant per pound of air. This means that, in a typical 500-ton machine, the loss from purge is less than three-quarters of an ounce of refrigerant annually.

During minor service for centrifugal chillers, emissions are also reduced to near zero levels. Minor service for these chillers is characterized by procedures like changing purge and oil filters. The "near zero" emissions centrifugal chiller is equipped with a complete system of isolation valves to allow evacuation and extraction of nearly all refrigerant from the oil filtration system. This reduces emissions during minor service to near zero losses.

Refrigerant transfer during major repair or overhaul also benefits from special valving arrangements that allow refrigerant to be added to the equipment and recovered with virtually non-measurable losses of refrigerant.

Refrigerant Availability

At the September 1997, 10-year anniversary meeting of the Montreal Protocol, the parties reaffirmed that the phaseout dates established at earlier meeting, would remain in tact and would not be accelerated. This agreement was and is extremely important for building owners since it gives assurances that long term plans for managing the CFC-Free transition can be executed without fear of another round of changes.

Obviously, "near zero" emissions have significant implications for the question of the future availability of refrigerants. Said simply, a chiller that does not loose its refrigerant during normal operations, routine maintenance and major overhaul does not require recharging. For example, a 500 ton centrifugal chiller with an emissions rate of 0.50 percent will loose 5 pounds of refrigerant recharge each year. A 30-year supply of HCFC-123 (the anticipated useful lifetime of a chiller) will fit into two six-gallon containers and, at current prices, cost $600.

Although the U.S. Environmental Protection Agency (EPA) has set a date for eventual phaseout of HCFC-123 production in the next century – based on the fact that it does have an ozone depletion potential, however low – recent studies have raised questions about this policy's logical basis. Quite simply, it typically takes approximately three to five years for substances to reach the upper atmosphere where they can affect stratospheric chemistry.. HCFC-123 has an atmospheric life of 1.4 years. This means that very little HCFC-123 ever reaches the stratosphere.[6]

Dr. Sherwood Rowland, a noted atmospheric scientist and one of the two scientists credited with originating the theory of stratospheric ozone depletion recently stated that,

> *"I am certainly in favor that HCFC's should be divided according to their lifetimes, and the [HCFC]-123, for instance, has a short lifetime. I don't see the sense in including it in with the very long lifetime molecules, because most of it is not going to make it to the stratosphere.*

...If the world's governments had asked me for my advice, I would have

divided (chlorine-containing compounds) somewhere along the line of lifetimes shorter than five years. I would put them in different categories and not be worried about them for the present time." [7]

Also, at a 1992 meeting in Copenhagen aimed at following up on implementation of the Montreal Protocol, one scientist challenged the group to measure any quantity of HCFC-123 in the stratosphere. This is based simply on the compound's short atmospheric life and the low emission rate of low-pressure chillers.

The short atmospheric lifetime combined with low ozone depletion level, especially compared to CFC-11, are the reasons HCFC-123 will retain its current U.S. phaseout date of 2030. And why, when combined with its low GWP and high efficiency, there has been discussion of extending or even eliminating HCFC-123’s phaseout date. [8]

In a related more recent finding, noted atmospheric scientist Donald J. Wuebbles and refrigerant consultant James M. Calm, in an article written for Science, suggest that a revision to the Montreal Protocol to allow continued use of HCFC-123 in closed refrigeration systems would have negligible effect on the chlorine loading in the upper stratosphere. They further observe that chemicals, such as HCFC-123 that combine short atmospheric lifetimes with the potential for energy savings, offer benefits that outweigh the consequences of very low ODP and GWP. They conclude that because of new global environmental concerns, such as proposed in the Kyoto Treaty, the careless elimination of options (i.e. HCFC-123 vis-à-vis the Montreal Protocol as currently written) can be more harmful than beneficial. [9]

CHILLERS UP TO 10 YEARS OLD

Up to now, we have been discussing replacing aging chillers, but what options are available for newer chillers, say up to 10 years old. The chillers in this category are typically good candidates for **retrofit**. They are newer and typically reflect improved efficiencies. Perhaps most importantly, HVAC machines in this age category have much of their useful life remaining.

There are some very real and significant advantages to retrofitting chillers as opposed to replacing them with non-CFC using chillers. First, retrofit is typically 50 to 70 percent less expensive than replacing. Advantages include:

- Less downtime – in some cases retrofits can be accomplished in as few as three days.
- Reduced system and piping modifications – no need to change out pumps or piping;
- The ability to continue to use sound chillers (if you have paid the price to properly maintain your existing chillers you can continue to have that investment pay off with 20 to 30 years of additional chiller life).
- The retrofit process adds new life to your chillers because most major mechanical parts are replaced or reconditioned.

In this category, planning can save capital expenditures. Proper planning can conserve capital. For example, conversions can be done economically at the time of major overhauls. Overhauls are recommended by all major chiller manufacturers every seven to 10 years. What does retrofit entail?

- During retrofit, all the gaskets, "O" rings and seals on the chiller must be changed since they are not compatible with the alternative and traditional refrigerants.
- Normally, the motor is removed and frequently sent to a motor rewind shop to be inspected or rewound. This is an excellent time to replace hermetic motors with ones that are compatible with both the traditional and the alternative refrigerants.
- While the machine is open for conversion and overhaul, the impellers must be trimmed or replaced and the refrigerant orifice plates must be reselected and changed.

There are a number of other retrofit options available to owners, one of which is the option to replace the existing chiller compressor with a new compressor while making the rest of the chiller compatible with the new refrigerant. This option is especially attractive where the existing chiller manufacturer does not offer a retrofit option and the chiller is located in such a hard-to-reach location that replacement is not possible. This option offers some very good capacity and efficiency improvements and can also provide a payback on utility cost savings.

Containment devices such as high efficiency purges, service fittings, etc. should be installed. Finally, you should insure that the equipment room must meet ASHRAE Standard 15 requirements.

By doing the conversion at the time of the major overhaul, owners can save between $10,000 and $15,000 on the conversion of a typical 500-ton hermetic centrifugal chiller, if the conversion is done simultaneously with the overhaul. I would strongly encourage maintenance personnel to look into using a computerized spreadsheet or other planning tool, to schedule, year by year, for these future major overhauls and to incorporate the conversion at the time of scheduled overhauls.

Predicting chiller performance after retrofit must be done by the chiller manufacturer to ensure it will be capable of handling the building load using a new, environmentally acceptable refrigerant. Many options come into play here. If the building load is significantly lower than original design, the retrofitted chiller can be selected at a reduced tonnage thereby allowing for an improved efficiency at the reduced tons. In some cases, chiller efficiency can be improved to where it is better than the original chiller efficiency. In those cases, the project will have a payback based on utility cost savings.

CHILLERS 10-20 YEARS OF AGE

Yes, we have jumped out of chronological order, going from the oldest to the youngest chillers. That is because middle age chillers 10-20 years old present the greatest evaluation challenges. The owner must choose between the more expensive, but more efficient, replacement option and the less expensive, but less efficient, conversion option.

Experience has shown that a valuable first step in making this difficult choice is to contact the original equipment manufacturer (OEM). From chiller records, OEMs can ascertain the original performance characteristics and then run computer programs that will provide the capacity and efficiency data, not only on the traditional refrigerant, but on the alternative refrigerant as well. In addition, information can be obtained regarding the cost of reaching capacity and efficiency levels.

Once the cost and efficiency numbers are known for both the conversion and the replacement options, design professionals can use computerized life-cycle cost analysis programs, like TRACE® or System Analyzer™, to provide information such as simple pay back, internal rate of returns, cash flow or other valuable financial data to equip the owner to make an informed decision.

To put this decision-making process into perspective, a conversion typically costs only 20 - 40 percent of the replacement chiller's total installed cost. However, depending on the efficiency differences, the entire first cost difference may be paid back in an extremely short time period; a time period that can be determined accurately and dependably.

Another important additional factor when deciding between conversion and replacement, as discussed earlier, is the availability of microprocessor-based controls for new chillers.

You will develop possible solutions through the full analysis of your containment responsibilities and options, as well as the options and opportunities available in conversion and replacement. Analysis will be based on economic and environmental considerations with a view toward answering the question only you can address: "Which system will provide my customers with the most comfortable working environment in a cost-effective and environmentally sound manner?"

And speaking of systems, when owners are making decisions in the process of becoming CFC free they are encouraged to look at all aspects of the chiller plant system. This includes items such as the cooling tower, pumps and controls, and to examine all options...electric, absorption, ice storage or a combination of all of these.

FOR MULTIPLE CHILLER OWNERS

Stockpiling CFC’s from retrofitted chillers for later use in CFC-based machines is an option for building owners and managers who are responsible for multiple chillers of varying ages. This approach allows chiller change-out to proceed gradually over a number of years.

One method to accomplish this without the up-front cost of a big refrigerant stockpile is to use what is called a "working stockpile." With this approach, one or more chillers are retrofitted to alternative refrigerant capability, but the original CFC refrigerant is recharged back into the chiller. The chiller is now fully capable of operating on either CFC or alternative refrigerants. Should the operator need the CFC refrigerant at another location, it is simply removed from the retrofitted chiller and replaced with the new, EPA approved, environmentally acceptable, alternative refrigerant (HCFC-22, HFC-134a, and HCFC-123) This program reduces the up-front conversion cost, reduces stockpiling costs and eliminates stockpiling risk. Retrofits are definitely a growing vogue. Here are a number of reasons why:

- Agency policy aims toward greening operations.
- Agencies that own multiple chillers have developed long-term plans to systematically replace and retrofit chillers in a logical sequence.
- Since equipment failures prompt major overhauls, a building manager also would have the unexpected opportunity to retrofit as part of the repair.

THE FUTURE

In the decade of the 1990’s, and beyond, the focus on improved energy efficiency will become absolutely critical. This message must be understood and internalized. Because of the focus on energy in the process of becoming CFC free, owners are encouraged to actively search for ways to improve efficiency by addressing all aspects of the system and not focus solely on the chillers themselves.

Whether the Kyoto Treaty becomes an international reality or not, the fundamental philosophy of the treaty, namely efficiency, conservation, and reduced emissions, will likely be quite pervasive, particularly in the government. In an effort to set an example for the rest of the country, budgets are already being proposed and measures, such as the Amendment to the Energy Policy Act of 1992, are embracing many of the provisions of the global climate change initiative. It is expected that energy efficiency regulations for products and for buildings (such as ASHRAE 90, and 10 CFR 435) will be improved in the future to yield greater minimum standards of efficiency.

Fortunately for all of us, the HVAC industry has set the standard for developing a wide range of products to fit your needs. While nobody can clearly foresee the future, it is safe to say that the trends we have seen over the past 20 years toward more energy-efficient products that are environmentally sustainable, will continue. Working in partnership with you, we will jointly do the right thing: for our customers, for our businesses and for our environment.

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